

## ORIGINAL RESEARCH

## KINEMATIC AND KINETIC VARIABLES DIFFER BETWEEN KETTLEBELL SWING STYLES

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## ABSTRACT

**Background:** Kettlebell (KB) and indian club swings (ICS) are used diversely for developing strength and power. It has been proposed that multiple swing techniques can be used interchangeably to elicit similar adaptations within performance training.

**Hypothesis/Purpose:** It was hypothesized that there will be not be a difference in peak joint angles between types of swings. Furthermore, given the nature of the overhead kettlebell swing (OKS), it was hypothesized that the OKS will be associated with a greater cycle time and a greater vertical impulse compared to shoulder height swing (SKS) and ICS. The purpose of this study was to analyze the kinematics and kinetics of the SKS, OKS, and ICS.

**Study Design:** Cross-sectional cohort\_

**Methods:** Fifteen healthy subjects underwent 3D biomechanical analysis for assessment of kinematic and kinetic data. Subjects performed two trials of ten repetitions at full effort for each swing in a randomized order using either a standard set of 0.45 kg indian clubs or sex specific KB loads (Female = 12kg, Male = 20kg). Lower extremity sagittal plane kinematics and kinetics were analyzed for peak values during the down and up portions of the swing patterns. Statistical analyses were carried out utilizing one-way ANOVAs ( $p < .05$ ) and effect size indices.

**Results:** Cycle time for the OKS was 34% longer than the SKS and ICS ( $p < .001$ ;  $ESI_{SKS} = 2.09$ ,  $ESI_{ICS} = 1.92$ ). In general, ankle (SKS:  $0.82 \pm 0.16$ ; OKS:  $0.90 \pm 0.21$ ; ICS:  $0.60 \pm 0.15$  BW\*BH) and hip joint moments (SKS:  $2.34 \pm 0.68$ ; OKS:  $2.32 \pm 0.53$ ; ICS:  $1.84 \pm 0.47$  BW\*BH) and joint powers, along with peak vertical ground reaction forces (vGRF) (SKS:  $0.98 \pm 0.14$ ; OKS:  $0.96 \pm 0.10$ ; ICS:  $0.86 \pm 0.11$  BW/s), were higher in the SKS and OKS than the ICS ( $p < .001$ ; ankle:  $ESI_{SKS/OKS} = 0.43$ ,  $ESI_{SKS/ICS} = 1.42$ ; hip:  $ESI_{SKS/OKS} = 0.03$ ,  $ESI_{SKS/ICS} = 0.87$ ; vGRF:  $ESI_{SKS/OKS} = 1.80$ ,  $ESI_{SKS/ICS} = 0.20$ ). There were no observed differences found in peak joint angles between the movements.

**Conclusion:** Although these swings are kinematically similar, the differing kinetic demands of these exercises may be important in selecting the right training modality for specific strength and power training.

**Level of Evidence:** 2

**Keywords:** Kettlebell training, power, resistance training, strength

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## INTRODUCTION

Strength and power are essential for athletic performance.<sup>1-6</sup> Athletic tasks such as jumping require a high force production rate to enhance accomplishments.<sup>7</sup> Allen et al.<sup>8</sup> observed that that increasing strength improved triple jump performance. Marian et al.<sup>9</sup> concluded that eight weeks of power squat jump training increased maximal strength, vertical jump and sprint performance in recreational athletes. As a result, implementing strength and power training to enhance athletic development is ideal to augment athletic capabilities.<sup>4</sup>

Traditional strength and power training involves a large amount of space and equipment, requiring budgets up to 60,000 dollars per year.<sup>6</sup> Many training facilities, however, only have modest space and resources<sup>6,10</sup> with the average high school strength and conditioning facility having an average of 9.1 square feet per athlete.<sup>10</sup> Furthermore, lower school enrollment has a direct correlation to budgetary concerns.<sup>6</sup> Alternative training approaches may optimize space and financial limitations for strength and conditioning training.<sup>5,10,11</sup> In response, performance specialists have focused on strength and power training requiring minimal equipment.<sup>12</sup>

In recent years, alternative training approaches to strength and power development have gained popularity; particularly the use of kettlebells (KB) and indian clubs.<sup>12</sup> The design of the KB and indian club permits the center of mass to extend beyond the hand.<sup>3</sup> As a result, this implement design is conducive for whole body ballistic movements; that are similar to the clean, snatch and jerk in traditional weightlifting.<sup>3</sup> KB swings have been shown to help facilitate gains in strength, power and endurance.<sup>2,3,5,11,13</sup> Lake and Lauder<sup>2</sup> examined the effects of six weeks of KB or jump squat training on strength and power development. Both KB training and squat jump training were found to provide an increase of 9.8% and 19.8% in strength and power respectively, with no statistically significant differences between cohorts.<sup>2</sup> In another study by Manocchia and colleagues<sup>3</sup> investigating the transferability of KB training to other weightlifting exercises, a 10-week KB training cycle was shown to improve bench press by 14.2 kg and clean and jerk performance by 4.2 kg. These studies suggest the utility and transferability of KB training

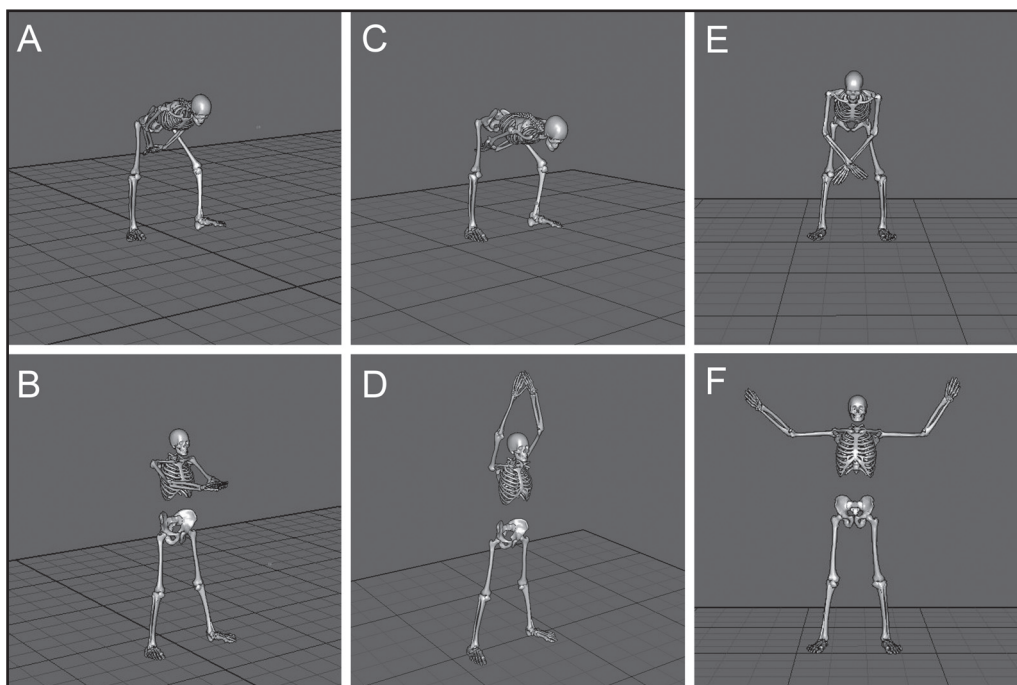
for the development of strength and power as compared to other more traditional methods.<sup>2,4,14</sup>

A common KB exercise is the shoulder height swing (SKS) (Figure 1: A, B).<sup>1,2,14-16</sup> Previous authors<sup>14,15,17</sup> have investigated the kinematics and kinetics of the SKS. Kim et al.<sup>17</sup> observed that beginners demonstrated greater range of motion in the shoulders and different angular joint velocities compared to KB experts. McGill et al.<sup>14</sup> concluded that the SKS exhibited loads to the lumbar spine that are in the opposite direction compared to the traditional deadlift. From the basic foundational principles of the SKS technique, the exercise can transform into various progressions. Two swing progressions that, to the authors' knowledge, have not been investigated within the literature are the overhead KB swing (OKS)<sup>18</sup> and the indian club swing (ICS).<sup>19</sup> The OKS is a KB swing with the KB momentum ceasing at full shoulder flexion, and elbow extension (Figure 1 C, D).<sup>18</sup> The ICS consists of two lightweight clubs, one held in each hand, positioned with the upper extremities in 90 degrees of shoulder abduction and elbow flexion, followed by upper limb horizontal adduction while initiating a hip hinge pattern (Figure 1: E, F).<sup>19</sup> Previous research has assessed the transferability of KBS and ICS for the development of strength and power;<sup>20</sup> however, there is little information in the literature regarding the different mechanical demands between the SKS, OKS and ICS.

In order to develop a better understanding of the different KB and IC training, this study examined the varying kinematic and kinetic demands of the different KB and IC swings. The purpose of this study was to analyze the kinematics and kinetics of the SKS, OKS, and ICS. Due to the parameters of the swings, it was hypothesized that no differences in peak joint kinematics would be found, (angles and velocities) which would suggest the swings are functionally similar. Furthermore, given the nature of the OKS, we hypothesize the OKS will be associated with a greater cycle time and a greater vertical impulse compared to SKS and ICS.

## METHODS

To describe the mechanical demands of the SKS, OKS and ICS, 3D motion capture during a randomized exercise allocation was utilized.



**Figure 1.** Visual representation of the shoulder height kettlebell swing, (SKS: A, B) overhead kettlebell swing, (OKS: C, D) and indian club swing (ICS: E, F) during the down and up phases, respectively.

## Subjects

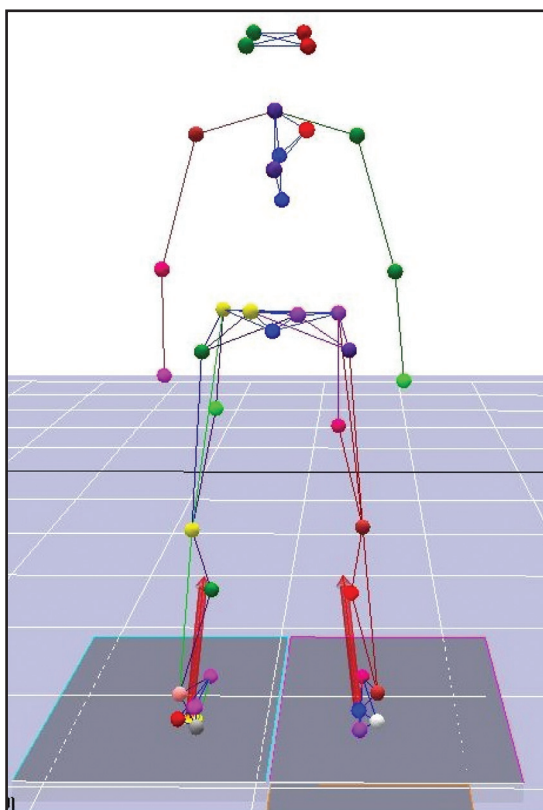
Fifteen healthy recreational athletes, consisting of nine males and six females ( $n=15$ ; age,  $26.7 \pm 4.3$  years; height,  $1.76 \pm 0.09$  m; mass,  $77.6 \pm 13.5$  kg) volunteered for this study. A convenience sample was employed to recruit subjects from the local university community. Inclusion criteria included that subjects reported no pain during the exercises, were free from injury in the prior six months and had at least six months of past experience with KB or indian club training. Exclusion criteria consisted of participants reporting pain currently or in the prior three months, an injury in the prior six months that limited participation in athletic activities, any surgery in the last 12 months, and those who had not received past KB or indian club instruction. All subjects were informed of the risks and benefits of the testing and written consent was obtained. The Duke University Health System Institutional Review Board approved this study. All data were collected and analyzed at the Michael W. Krzyzewski Human Performance Laboratory.

## Kettlebell swing analysis

Participants were asked to wear spandex shorts and shirt and were given 10 minutes for instruction and

warm-up prior to data collection. Participants were fitted with a modified Helen-Hayes marker set with a total of 48 retro-reflective markers placed on various anatomic landmarks (Figure 2). Three-dimensional marker coordinate data were captured using an eight camera motion capture system sampling at 120 Hz (Motion Analysis Corporation; Santa Rosa, CA), while embedded force plates (AMTI, Watertown, MA) sampling at 1200 Hz were used to collect tri-axial ground reaction forces. The retro-reflective markers were placed by the same investigator for each participant to limit interrater variability between data collections.

Before each movement, a single test administrator demonstrated each swing exercise and gave standardized minimal verbal cues. For all exercises, universal instruction consisted of instructing the patient to give full effort. SKS directions entailed swinging the KB to shoulder height. OKS directions were swinging the KB to the full overhead position, and ICS coaching focused on pulling the clubs behind the body.<sup>18, 19</sup> Full overhead position during the OKS was self determined by each subject due to each subjects past KB experience. The ICS consisted of the athlete forcefully adducting the shoulders and



**Figure 2.** *Biomechanical Dynamic Marker Set*

extending the elbows bilaterally, while concurrently initiating hip flexion and slight knee flexion. At this bottom position, the spine was held in neutral. The swing was reversed with the initiation of hip extension and bilateral shoulder abduction. The swing was completed when the indian clubs were back to the original 90 degrees of shoulder abduction and the hips were slightly flexed. After each exercise trial, a volitionally determined rest break was given to each patient to minimize fatigue and preserve external validity to further mimic a training or rehabilitation setting. The medial instep of each foot was aligned vertically to the axilla to standardize stance width.<sup>18</sup> Subjects performed two trials of 10 repetitions, at full effort for each swing type. To account for variations in trial initiation and completion, only the middle eight swings were used for analysis. Each subject used a standard set of 0.45 kg indian clubs and sex specific KB's (Female = 12 kg, Male = 20 kg). The sex specific KB masses were originally described by Pavel Tsatsouline in the Kettlebell Strong First Certification. Data were collected while subjects performed swing patterns with each foot on a separate force plate. Lower extremity sagittal plane kinematics and

kinetics were analyzed during the down and up portion of the swing patterns.

### Data Analysis

Coordinate data were filtered using a fourth-order low-pass Butterworth filter at 7Hz, and the ground reaction force data were filtered at 100Hz. Kinematic and kinetic data were calculated using Visual 3D (C-Motion, Bethesda, Maryland, USA). Joint angles were calculated as Cardan angles between segments with an order of sagittal plane, followed by frontal plane, and then transverse plane. Inverse dynamics were used to calculate joint moments, expressed as internal moments and normalized to mass and height. Ground reaction forces were normalized to and expressed as a percentage of body mass. The total cycle time for each swing was calculated from the peak of the vertical displacement of the motion to the subsequent vertical peak and averaged across swing type. To account for individual differences in timing of the swing cycle, each swing was normalized to the cycle time for analysis. Each variable of interest was extracted from these individual swings and averaged across swings and trials. Data were averaged between right and left limbs to account for slight variations in technique across participants. The six kinematic variables of interest included peak hip flexion, peak knee flexion, peak dorsiflexion, as well as the peak joint angular velocities at the hip, knee, and ankle (Table 1). The kinetic variables of interest included peak hip extension moment, peak knee extension moment, peak plantarflexion moment, peak hip extension power, peak knee extension power, peak ankle plantarflexion power, the peak vertical ground reaction force (vGRF), and vertical impulse before and after peak vGRF (Table 2). These dependent variables were calculated and extracted using custom software developed in Matlab R2010a (MathWorks Inc., Natick, MA).

### Statistical Analysis

Statistical analyses were carried out using a series of one-way repeated-measures ANOVAs to assess differences between the SKS, OKS, and ICS. To account for increased Type I error from multiple comparisons, a conservative alpha was used ( $\alpha = .01$ ). A Bonferroni adjustment considering the 15 total comparisons would result in a  $p < .003$ , which would

**Table 1.** Mean  $\pm$  standard deviation, ANOVA and effect size index results for cycle time and kinematic variables of interest for each condition.

Variable	Shoulder height kettlebell swing (SKS)	Overhead kettlebell swing (OKS)	Indian club swing (ICS)	<i>p</i> -value	ESI <sub>SKS/OKS</sub>	ESI <sub>SKS/ICS</sub>	ESI <sub>OKS/ICS</sub>
Peak ankle dorsiflexion (deg)	11.3 $\pm$ 6.4	10.5 $\pm$ 6.5	9.7 $\pm$ 6.3	.385	0.12	0.25	0.13
Peak knee flexion (deg)	60.8 $\pm$ 16.4	61.8 $\pm$ 16.2	62.2 $\pm$ 19.8	.787	0.06	0.08	0.02
Peak hip flexion (deg)	69.8 $\pm$ 9.3	69.7 $\pm$ 10.4	73.7 $\pm$ 12.8	.081	0.01	0.35	0.34
<b>Peak ankle plantarflexion velocity (deg/s)</b>	<b>89.4 <math>\pm</math> 32.8 *</b>	<b>72.2 <math>\pm</math> 29.7 *</b>	<b>64.3 <math>\pm</math> 33.9 *</b>	<b>.005</b>	<b>0.55</b>	<b>0.75</b>	<b>0.25</b>
<b>Peak knee extension velocity (deg/s)</b>	<b>257.3 <math>\pm</math> 41.4 †</b>	<b>207.1 <math>\pm</math> 49.0</b>	<b>252.1 <math>\pm</math> 53.2 †</b>	<b>.003</b>	<b>1.11</b>	<b>0.11</b>	<b>0.88</b>
Peak hip extension velocity (deg/s)	303.4 $\pm$ 66.2	270.5 $\pm$ 60.3	315.7 $\pm$ 70.1	.068	0.52	0.18	0.69
<b>Cycle Time (s)</b>	<b>1.45 <math>\pm</math> 0.16 †</b>	<b>1.92 <math>\pm</math> 0.29</b>	<b>1.44 <math>\pm</math> 0.21†</b>	<b>&lt; .001</b>	<b>2.09</b>	<b>0.05</b>	<b>1.92</b>
Notes. <i>p</i> < .05 considered significant.							
† significantly different than OKS							
* all swings significantly different							

increase the probability of a Type II error. Tukey's HSD post-hoc analysis was used to identify significant pairwise comparisons. Effect size indices (ESIs) were calculated in order to understand the clinical relevance that was not due to sample size. Statistical analyses were completed using SPSS 21 (SPSS Inc, IBM, Chicago, Illinois).

## RESULTS

No significant differences were observed for peak ankle or knee angles across swing types. While no significant difference was observed in peak hip flexion angles, there was a small effect between SKS and ICS (ESI=0.35) and OKS and ICS (ESI=0.35). A small effect was exhibited in peak ankle plantarflexion velocity during the SKS compared to the OKS (ESI=0.55), although this was not statistically significant. However, peak plantarflexion SKS velocity was greater than the ICS ( $p = .005$ ; ESI=0.75). Knee extension velocity was greater for the SKS compared to OKS ( $p = .003$ ; ESI=1.11) and OKS related to ICS ( $p = .003$ ; ESI=0.88). No differences were found between swing types for hip extension velocity; nevertheless there was a moderate effect between SKS and OKS (ESI=0.52) and OKS and ICS (ESI=0.69). Cycle time for the SKS was significantly shorter than the OKS ( $p < .001$ ; ESI=2.09), while equal to the ICS

(ESI=0.05). The OKS cycle time was also greater than the ICS ( $p < .001$ ; ESI=1.92) (Table 1).

The vertical impulse before the peak vGRF, during the down portion of the swing, was smaller in the SKS compared to the OKS ( $p < .001$ ; ESI=1.80), which was greater than the ICS ( $p < .001$ ; ESI=1.23). The SKS and ICS vertical impulse prior to the peak vGRF were comparable (ESI=0.20). The vertical impulse after peak vGRF was less in the SKS in relation to the OKS ( $p < .001$ ; ESI=1.14). The ICS displayed the least impulse after peak vGRF ( $p < .001$ ; ESI<sub>SKS</sub>=2.00; ESI<sub>OKS</sub>=3.00). Unsurprisingly, the peak vGRF was greater in both the SKS and OKS (ESI=.17) when compared to the ICS ( $p < .001$ ; ESI<sub>SKS</sub>=0.96; ESI<sub>OKS</sub>=0.95). Peak ankle plantarflexion moments were similar between the SKS and OKS; but displayed a moderate effect (ESI=0.43). The SKS and OKS were both significantly greater than the ICS ( $p < .001$ ; ESI<sub>SKS</sub>=1.42; ESI<sub>OKS</sub>=1.67). No significant differences were displayed in knee extension moment. Peak hip extension moment was similar between the SKS and OKS (ESI=0.03), which were both larger than the ICS ( $p < .001$ ; ESI<sub>SKS</sub>=0.87; ESI<sub>OKS</sub>=0.96). Similarly, peak ankle plantarflexion power was greater in the SKS and OKS (ESI=0.15) compared to the ICS ( $p = .001$ ; ESI<sub>SKS</sub>=2.82; ESI<sub>OKS</sub>=2.32). No significant difference

<b>Table 2.</b> Mean $\pm$ standard deviation, ANOVA and effect size index results for kinetic variables of interest for each condition.							
Variable	Shoulder height kettlebell swing (SKS)	Overhead kettlebell swing (OKS)	Indian club swing (ICS)	<i>p</i> -value	ESI <sub>SKS/OKS</sub>	ESI <sub>SKS/ICS</sub>	ESI <sub>OKS/ICS</sub>
<b>Vertical Impulse prior to peak vGRF (BW*s)</b>	<b>0.43 <math>\pm</math> 0.07 ¥</b>	<b>0.61 <math>\pm</math> 0.13 ¥</b>	<b>0.45 <math>\pm</math> 0.13</b>	<b>&lt; .001</b>	<b>1.80</b>	<b>0.2</b>	<b>1.23</b>
<b>Vertical Impulse after peak vGRF (BW*s)</b>	<b>0.45 <math>\pm</math> 0.09 *</b>	<b>0.57 <math>\pm</math> 0.12 *</b>	<b>0.30 <math>\pm</math> 0.06 *</b>	<b>&lt; .001</b>	<b>1.14</b>	<b>2.00</b>	<b>3.00</b>
<b>Peak vertical ground reaction force (BW)</b>	<b>0.98 <math>\pm</math> 0.14 ¥</b>	<b>0.96 <math>\pm</math> 0.10 ¥</b>	<b>0.86 <math>\pm</math> 0.11</b>	<b>&lt; .001</b>	<b>0.17</b>	<b>0.96</b>	<b>0.95</b>
<b>Peak ankle plantarflexion moment (BW*BH)</b>	<b>0.82 <math>\pm</math> 0.16 ¥</b>	<b>0.90 <math>\pm</math> 0.21 ¥</b>	<b>0.60 <math>\pm</math> 0.15</b>	<b>&lt; .001</b>	<b>0.43</b>	<b>1.42</b>	<b>1.67</b>
Peak knee extension moment (BW*BH)	0.50 $\pm$ 0.36	0.47 $\pm$ 0.31	0.50 $\pm$ 0.37	.812	0.09	0.00	0.09
<b>Peak hip extension moment (BW*BH)</b>	<b>2.34 <math>\pm</math> 0.68 ¥</b>	<b>2.32 <math>\pm</math> 0.53 ¥</b>	<b>1.84 <math>\pm</math> 0.47</b>	<b>&lt; .001</b>	<b>0.03</b>	<b>0.87</b>	<b>0.96</b>
<b>Peak ankle plantarflexion power (BW*BH)</b>	<b>0.71 <math>\pm</math> 0.24 ¥</b>	<b>0.67 <math>\pm</math> 0.28 ¥</b>	<b>0.23 <math>\pm</math> 0.10</b>	<b>&lt; .001</b>	<b>0.15</b>	<b>2.82</b>	<b>2.32</b>
Peak knee extension power (BW*BH)	1.36 $\pm$ 0.83	0.98 $\pm$ 0.44	1.09 $\pm$ 0.70	.052	0.60	0.35	0.19
<b>Peak hip extension power (BW*BH)</b>	<b>5.22 <math>\pm</math> 2.18 ¥</b>	<b>5.40 <math>\pm</math> 1.92 ¥</b>	<b>3.55 <math>\pm</math> 1.39</b>	<b>&lt; .001</b>	<b>0.09</b>	<b>0.94</b>	<b>1.12</b>
Notes. <i>p</i> < .05 considered significant. BW = Body Weight, BH = Body Height ¥ significantly different than ICS; * all swings significantly different							

was evident in peak knee extension power across the three swing types; however there was a moderate effect between the SKS and OKS (ESI = 0.60) and SKS and ICS (ESI = 0.35). Lastly, peak hip extension power was greater in the SKS and OKS (ESI = 0.09) when compared to the ICS ( $p < .001$ ; ESI<sub>SKS</sub> = 0.94; ESI<sub>OKS</sub> = 1.12)(Table 2).

## DISCUSSION

Strength and power is essential for athletic performance.<sup>1,3-5,12</sup> Developing strength and power through training methods that use minimal equipment is beneficial for space and budgetary demands.<sup>5,10,11</sup> KB and indian club training are alternative methods in which to develop strength and power.<sup>12,19</sup> As a result,

understanding the different mechanical demands of varying KB and indian club exercises is necessary to select the proper training modality for desired adaptations.<sup>14, 20</sup> The purpose of this study was to analyze the mechanical demands imposed by SKS, OKS, and ICS. In support of the hypothesis, there were no differences in peak ankle or knee joint angles or hip extension velocity for the SKS, OKS or ICS. However, peak plantarflexion velocity was greater in the SKS compared to the OKS, which was greater than the ICS. The SKS had a superior knee extension velocity compared to the OKS, while the ICS had a similar knee extension velocity in relation to the SKS. The SKS displayed a decreased cycle time than the OKS, which was larger than the ICS. Contrary to the

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hypothesis, the SKS and ICS displayed a bigger vertical impulse prior to peak vGRF in contrast to the OKS. However, in support of the hypothesis, the SKS and ICS had a decreased vertical impulse after peak vGRF in relation to OKS.

Consistent with the hypothesis, there were no significant differences in peak joint angles between any of the various swing types. This suggests the swings are mechanically similar and, given the similarities in the lowest positions, move through a comparable lower extremity range of motion. While not statistically significant, when variance was normalized, a moderate difference was observed in peak hip flexion between the KB swings (SKS and OKS) and ICS. While there are no studies to the authors' knowledge investigating ICS, the greater peak hip flexion may be due the specific techniques employed for the SKS, OKS and ICS.<sup>16,18,19</sup> As previously described, the KB used in the SKS and OKS must pass between the knees to the bottom position.<sup>16</sup> This is in contrast to the ICS, in which the indian clubs project in a lateral downward path.<sup>19</sup> From this trajectory, the hips may require increased range of motion, in order to allow the indian clubs to effectively pass the without striking the body, compared to the KB swings. The SKS displayed similar peak plantarflexion velocity compared to the OKS, which were both greater than the ICS. The SKS was associated with greater peak knee extension velocity than the OKS, which had a lesser peak knee extension velocity in comparison to the ICS. The SKS and ICS had similar peak knee extension velocities. All three-swing variations displayed similar peak hip extension velocity. Future research is necessary in order to understand how different techniques employed by the KB and indian clubs can affect kinematics at both the trunk and upper extremity.

Supporting the hypothesis, the SKS presented with a 34% lesser cycle time compared to the OKS, which was greater than the ICS. While no studies to the authors' knowledge have examined the OKS, two previous studies<sup>14,20</sup> have investigated the mechanical workload of a similar exercise, the KB snatch. The KB snatch is a unilateral KB swing, terminating in full shoulder flexion and elbow extension.<sup>13,20</sup> While both the OKS and KB snatch end in an overhead position, the KB snatch utilizes a single hand

swing in comparison to the OKS two handed swing. Furthermore, the KB snatch integrates a more vertical trajectory to reach overhead, compared to the more curvilinear arc of the OKS.<sup>18,19</sup> Lake and colleagues<sup>20</sup> discerned that the KB snatch had greater vertical center of mass displacement (22 cm vs. 18 cm) compared to SKS. The bilateral OKS terminal position is similar to the unilateral KB snatch end point.<sup>18</sup> With each swing beginning with a similar starting point, the OKS ending overhead caused a greater cycle time compared to the SKS and ICS.<sup>13-15,18</sup> While this study did not investigate upper extremity and spine kinematics and kinetics during the OKS swing, future studies are needed to understand the role these body parts play due to the overhead requirements elicited during this KB swing pattern.

Unsurprisingly, the SKS exhibited less vertical impulse during the propulsion (up) phase when compared to the OKS, which was larger than and ICS, while the SKS and ICS displayed similar vertical impulse during the propulsion phase. Furthermore, the vertical impulse during the braking (down) phase of the SKS was less in relation to the OKS, while larger in contrast to the ICS. This is consistent with previous work<sup>14, 20</sup> and may be attributed to the larger amount of additional mass associated with the kettlebells as compared to the indian clubs. In order to progress back to the standard KB swing bottom position; a decreased downward vertical displacement, and thus time, is required for the SKS and ICS when compared to the OKS.<sup>14, 20</sup> Previous authors<sup>21-23</sup> have discussed the importance of impulse in regards to power production. Knudson<sup>22</sup> has proposed that impulse establishes the degree and velocity of motion, and thus power is a non-optimal factor. Schilling et al.<sup>21</sup> demonstrated that an increase in impulse resulted in greater velocities and force within squatting. As a result, for a fixed mass, a larger force or a longer time period for a given force will result in greater velocity.<sup>21</sup> As a result, the vGRF is being absorbed over a shorter cycle time during the SKS or ICS in order to bring the KB or indian clubs back to bottom position.<sup>14,18,20,24,25</sup> This data suggests that while the SKS and OKS generate similar peak loads, the decreased SKS impulse created may be due to the shorter cycle time. The decreased cycle time observed in the SKS is associated with a

smaller amount of time under tension, which may elicit lower internal joint and tissue loads than OKS during the swing-braking (down) phase, while simultaneously generating similar peak loads as the OKS.<sup>26</sup> The peak vGRF was similar between the SKS and OKS; which were both greater than ICS (Table 1). These findings support previous work of Lake and colleagues,<sup>20</sup> in which the KB snatch and the SKS displayed similar vertical propulsion mean force values of 271.89 N and 291.37 N respectively. The OKS requires greater overhead mobility in order to proceed to terminal position,<sup>18</sup> while the SKS and ICS proceed only to shoulder height.<sup>2,19</sup> The similar peak vGRF observed between the SKS and OKS, suggests these swings require similar lower extremity force outputs to reach overhead and shoulder heights.<sup>20</sup>

The SKS and OKS exhibited greater peak ankle plantarflexion moments and peak hip extension moments compared to the ICS. Similarly, the two KB swings (SKS and OKS) were associated with greater peak ankle plantarflexion and peak hip extension power production compared to the ICS. These findings are similar to those from Lake and Laudner's study,<sup>20</sup> in which different KB swing types had comparable power outputs. Since all three swings displayed similar lower extremity joint excursion and hip extension velocities, the main component discrepancy between the KB swings and ICS is due to the force needed to propel the dissimilar weighted instruments, as displayed with the SKS and OKS demonstrating greater peak vertical vGRF compared to the ICS. The indian clubs utilized within this study had a mass of 0.45 kg. This is in contrast to the 12 and 20 kg sex specific KB's employed for the SKS and OKS respectively. Unsurprisingly, these mass differentials required subjects to utilize more force during the SKS and OKS, and thus more power from the hip and plantarflexors compared to the ICS. Future research is necessary in order to understand how different techniques employed by the KB and indian clubs can affect power and force production.

### Limitations

As with any investigation, there are limitations. The primary flaws within this study are due to the pre-determined sex specific KB's. Different subjects had varying strength and force production capacity,

beyond sex specificity. As a result, having standardized KB's could create different mechanical outputs, depending on the strength and power abilities of each individual. Furthermore, the subjects in the study had dissimilar KB and indian club swinging experience. Additional investigation is necessary in order to understand the effect past KB and indian club training experience has on the proficiency of mechanical outputs.

### CONCLUSION

In conclusion, while the SKS, OKS and ICS had overall similar mechanical characteristics; there were specific differences within each exercise. Specifically, the SKS exhibited a shorter cycle time and less downward and upwards-vertical impulse compared to the OKS. Furthermore, the SKS and OKS displayed greater peak moments and power from ankle plantarflexion and hip extension and greater vGRF compared to the ICS. This is the first study to compare kinematics and kinetics of the standard shoulder height kettlebell swing to the overhead kettlebell swing and the indian club swing. Understanding the different mechanical demands of the SKS, OKS, and ICS can facilitate selecting an appropriate exercise for the desired strength and power training adaptation.

### REFERENCES

1. Hulseley CR, Soto DT, Koch AJ, et al. Comparison of kettlebell swings and treadmill running at equivalent rating of perceived exertion values. *J Strength Cond Res.* 2012;26(5):1203-7.
2. Lake JP, Lauder MA. Kettlebell swing training improves maximal and explosive strength. *J Strength Cond Res* 2012; 26(8):2228-33.
3. Manocchia P, Spierer DK, Lufkin AK, et al. Transference of kettlebell training to strength, power, and endurance. *J Strength Cond Res.* 2013;27(2):477-84.
4. McKewon I, Chapman DW, Taylor K, et al. Time course of improvements in power characteristics in elite development netball players entering a full time training program. *J Strength Cond Res.* 2016;30(5):1308-15.
5. Otto WH 3rd, Coburn JW, Brown LE, et al. Effects of weightlifting vs. kettlebell training on vertical jump, strength, and body composition. *J Strength Cond Res* 2012;26(5):1199-202.
6. Judge LW1, Petersen JC, Bellar DM, et al. The current state of NCAA Division I collegiate strength facilities:

- size, equipment, budget, staffing, and football status. *J Strength Cond Res.* 2014;28(8):2253-61.
7. Hay JG. Citius, altius, longius (faster, higher longer): the biomechanics of jumping for distance. *J Biomech.* 1993;26;7-21.
8. Allen SJ, Yeadon MR, King MA. The effect of increasing strength and approach velocity on triple jump performance. *J Biomech.* 2016; Oct 19.
9. Marian V, Katarina L, David O, Matus K, Simon W. Improved maximum strength, vertical jump and sprint performance after 8 weeks of jump squat training with individualized loads. *J Sports Sci Med.* 2016;15(3):492-500.
10. Duehring MD, Ebben WP. Profile of high school strength and conditioning coaches. *J Strength Cond Res.* 2010;24(2):538-47.
11. Jay K, Jakobsen MD, Sundstrup E, et al. Effects of kettlebell training on postural coordination and jump performance: a randomized controlled trial. *J Strength Cond Res.* 2013; 27(5):1202-9.
12. Brumitt J, En Gilpin H, Brunette M, et al. Incorporating kettlebells into a lower extremity sports rehabilitation program. *N Am J Sports Phys Ther.* 2010;5(4):257-65.
13. Falatic JA, Plato PA, Holder C, et al. Effects of Kettlebell Training on Aerobic Capacity. *J Strength Cond Res.* 2015;29(7):1943-7.
14. McGill SM, Marshall LW. Kettlebell swing, snatch, and bottoms-up carry: back and hip muscle activation, motion, and low back loads. *J Strength Cond Res.* 2012;26(1):16-27.
15. Lake JP, Lauder MA. Mechanical demands of kettlebell swing exercise. *J Strength Cond Res.* 2012; 26(12):3209-16, 2012
16. Luke E, James F, James S. A comparison of the effect of kettlebell swings and isolated lumbar extension training upon acute torque production of the lumbar extensors. *J Strength Cond Res.* 2016; 30(5):1189-95.
17. Kim YK, Back CY, Joo JY, Park CH, Moon CW. Kinematic comparisons of kettlebell two arm swings between experts and beginners. ISBS-Conference Proceedings Archive. 2016. 34. 2.
18. Tsatsouline P. Enter the Kettlebell. St. Paul, MN: Dragon Door Publications, Inc., 2006.
19. Cook, G. Jones B, Thomas E. Club Swinging Essentials. Chatham, VA: Functional Movement Systems Inc., 2010.
20. Lake JP, Hetzler BS, Lauder MA. Magnitude and relative distribution of kettlebell snatch force-time characteristics. *J Strength Cond Res* 2014;28(11):3063-72.
21. Schilling BK, Falvo MJ, Chiu LZ. Force-velocity, impulse-momentum relationships: implications for efficacy of purposefully slow resistance training. *J Sports Sci Med.* 2008; 2(2); 299-304.
22. Knudson DV. Correcting the use of the term "power" in the strength and conditioning literature. *J Strength Cond Res.* 2009;23;1902-1908.
23. Lake JP, Mundy PD, Comfort P. Power and impulse applied during the push press exercise. *J Strength Cond Res.* 2014;28(9):2552-9.
24. Bobbert, MF, Huijing, P, and van Ingen Schenau, GJ. Drop jump II. The influence of dropping height on the biomechanics of jumping. *Med Sci Sports Exerc.* 1987;19: 339-346.
25. McNitt-Gray, JL. Kinematics and impulse characteristics of drop landings from three heights. *Int J Sport Biomech.* 1991;7: 201-224.
26. Mohamad NI, Cronin JB, Nosaka KK. Difference in kinematics and kinetics between high- and low-velocity resistance loading equated by volume: implications for hypertrophy training. *J Strength Cond Res.* 2012;26(1):269-75.